

Final Report

**NASA Grant NAG3-2309
(account #359-4163)**

**Workshop on Boundary Layer Transition
and Unsteady Aspects of Turbomachinery**

**John E. LaGraff
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Abstract

A workshop was organized on the topic of the title and held on August 20-23, 2000 at the Syracuse University Minnowbrook Conference Center in Blue Mountain Lake, New York. Attendance was by invitation only, forty-two guests attended and thirty presentations were made. Support was received from NASA Glenn Research Center, the US Air Force Office of Scientific Research the European Office of Aeronautical Research and Development, the Asian Office of Aeronautical Research and Development and Syracuse University. This workshop was the third in a triennial series beginning in 1993. A publication under a NASA CP number will be issued and include all abstracts. No full written papers were required. This report includes a list of attendees and the program of presentations. The next workshop is scheduled for August 2003.

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PROGRAM

MINNOWBROOK III

20-23 AUGUST 2000

Boundary Layer Transition and Unsteady Aspects of Turbomachinery Flows

Sunday - 20 August 2000

- 3:00 pm Minnowbrook Center Open to Participants/Registration begins
- 3:30 - 5:30 pm Visit to Adirondack Museum (optional)
- 6:30 pm Dinner
- 8:00 pm Welcome and Comments on Organization, Goals and Focus of Workshop
John LaGraff – Syracuse University
- 8:15 pm Roddam Narasimha – Keynote Speaker (30 minutes) - Indian Institute of Science
Subtransitions Revisited
- 9:00 pm Social get together

Monday - 21 August 2000

- 7:30 am Breakfast
- Session 1 - Turbomachinery Disturbance Environment**
Moderator: Ted Okiishi – Iowa State University
- 8:45 am Howard Hodson – Keynote (30 min) – Cambridge University, Whittle Laboratory
High Lift LP Turbines
- 9:15 am Greg Heitland – Honeywell Engines
Low Pressure Turbine Reynolds Number Effects: Small Engine Perspective
- 9:30 am J. Hourmouziadis – Technical University Berlin
Free Stream Unsteadiness and Turbulence. What is the Difference?
- 9:45 am Discussion
- 10:15 am BREAK

Session 2 Natural or Bypass Transition?

Moderator: Paul Gostelow – University of Leicester

- 10:45 am Gregg Walker – Keynote (30 min) – University of Tasmania
Assessment? Natural Versus Bypass Transition on Axial Compressor Blades - A Need for Re-
- 11:15 am Howard Hodson – Cambridge University, Whittle Laboratory
Separation Bubble and Turbulent Spot-Wake Interactions in the Turbomachinery Environment at Reynolds of Around 130,000
- 11:30 am Discussion
- 12:15 pm LUNCH

Session 3 Spots and Calmed Regions

Moderator: Chris Murawski – AFRL/PRTT/WPAFB

- 2:00 pm Terry Jones – Osney Labs-Oxford University
Visualization of Transitional Heat Flux in the Presence of Freestream and Pressure Gradient
- 2:15 pm Mark Johnson – University of Liverpool
The Initiation and Development of Turbulent Spots
- 2:30 pm O.N. Ramesh – Cambridge University, Whittle Laboratory
On The Dynamics of the Calmed Region Behind a Turbulent Spot
- 2:45 pm Howard Hodson – Cambridge University, Whittle Lab
The Visualisation and Measurement of the Onset, Turbulent Spot Production Rate, Intermittency and Heat Transfer During Wake-Induced Transition Using Thermochromic Liquid Crystals
- 3:00 pm Discussion
- 3:30 pm BREAK

Session 4 Modeling and Computation

Moderator: Lou Povinelli – NASA Glenn Research Center

- 4:00 pm David Ashpis – NASA Glenn Research Center
NASA Low Pressure Turbine Program
- 4:15 pm Erik Dick – University of Gent
ERCOFTAC Thematic Workshop on Transition
- 4:30 pm Johan Steelant – ESTEC-European Space Agency
Modelling of By-Pass Transition by Means of a Turbulence Weighting Factor
- 4:45 pm Thorwald Herbert – Ohio State University
Toward Direct Numerical Simulations of Turbine Flows
- 5:00 pm Discussion

6:30 pm Dinner
8:00 pm Working Group Meeting I

Tuesday - 22 August 2000

7:30 am Breakfast

Session 6 Wake Interactions

Moderator: Howard Hodson – Cambridge University, Whittle Laboratory

8:30 am Terry Simon – University of Minnesota
Experimental Investigation of Transition to Turbulence under Low-Pressure Turbine
Conditions: Measurements with and without Wakes

8:45 am Paul Durbin – Stanford University
Direct simulation of unsteady wakes and transition in a turbine passage

9:00 am Frank Smith – University College London
Unsteady Stator-Row with Wake Passings

9:15 am Paul Gostelow – University of Leicester
Relaxation Following Wake Impingement on Reattaching Flow

9:30 am Discussion

10:00 am BREAK

Session 7 Laminar Separation

Moderator: Terry Simon – University of Minnesota

10:30 am Tom Corke – University of Notre Dame
LPT Separation Control Using Phased Plasma Arrays

10:45 am Lennart Hultgren – NASA Glenn Research Center
Experimental Investigation of Separated and Transitional boundary Layers Under Low-
Pressure Turbine Airfoil Conditions

11:00 am Vassilios Theofilis – DLR Goettingen
Global Linear Instabilities in Laminar Separated Boundary Layer Flow

11:15 am Avi Seifert – NASA Langley Research Center/Tel Aviv University
Active Control of a Transitional Separation Bubble at Low Reynolds Number and
Elevated Free-Stream Turbulence

11:30 am Discussion

12:15 pm LUNCH

Session 8 Turbines

Moderator: Terry Jones – Osney Labs-Oxford University

- 2:00 pm Dan Dorney – Virginia Commonwealth University
Simulations of Boundary Layer Development in Low Pressure Turbines
- 2:15 pm Bob Boyle – NASA Glenn Research Center
Effect of Favorable Pressure Gradients on Turbine Blade Pressure Surface Heat Transfer
- 2:30 pm Ricardo Martinez-Botas – Imperial College
Mixed Flow Turbines: Unsteady Performance and Flow Characteristics
- 2:45 pm Aaron Byerley – USAF Academy
The Effect of Turbulence Length on Low Pressure Turbine Blade Heat Transfer
- 3:00 pm Discussion
- 3:30 pm BREAK

Session 9 Roughness/Free Stream Disturbances

Moderator: John LaGraff – Syracuse University

- 3:45 pm Jeffrey Crouch – Boeing Commercial Airplane Group
Estimating Transition Location in the Presence of Roughness and Free-Stream Disturbance
- 4:00 pm Don McEligot – Idaho National Engineering Lab
Effect of a Square Rib on Development of the Viscous Layer for a Turbulent Boundary Layer
- 4:15 pm Open
- 4:30 pm Torsten Fransson – KTH Stockholm
A Basic Nozzle Test Facility For Fluid-Structure Interaction in Transonic Flow
- 4:45 pm Discussion
- 6:30 pm Dinner
- 8:00 pm **Session 11**
Working Group Meeting II

Wednesday - 23 August 2000

7:00am Breakfast

Session 11

Moderator: Paul Gostelow – University Leicester

8:00 am Report of ad-hoc working groups – Ted Okiishi

Wrap-up discussion - Roddam Narasimha

9:45 am Conclusion of workshop

10:00 am First van leaves for Syracuse Airport

10:30 am Second van leaves for Syracuse Airport

11:30 a.m. Box lunches for all participants available on departure

12 noon Vacate Center